

[0003] Groundwater contamination, typically arising from petroleum storage tank spills or from intentional or accidental discharge of liquid hydrocarbons or compositions containing same, has become a problem of increasing concern. This type of contamination occurs not only at industrial complexes, but also in suburban neighborhoods, which would appear to be havens from such phenomena. The source of contamination in suburban neighborhoods or areas is very commonly automobile service station

sites at which antiquated or abandoned storage tanks have released gasoline, fuel oils, lubricants, and the like into the local groundwater. Other common sources of such noxious materials can include dry cleaning establishments and/or manufacturers or distributors of the tetrachloroethane which is used in the dry cleaning process.

[0004] Various remediation techniques have been utilized in the past for the treatment of contaminated groundwater in order to reduce or eliminate the contaminants, such as COCs. One of the most widely used systems is one based on so-called "pump and treat" technology. These systems withdraw the contaminated groundwater and a phase-separated product from a recovery well located in the groundwater and pump it to an above ground treatment facility. Thereafter, various treatment techniques, as are well known, are used to remove contaminants from the displaced groundwater. These "pump and treat" systems are relatively expensive to install and require that the remaining contaminants, which have been separated from the groundwater, be disposed in an environmentally friendly manner. These processes further increase the cost of the techniques.

[0005] One example of a known remediation system is disclosed in U.S. Patent No. 5,286,141. The '141 patent teaches oxidizing the source of groundwater contamination to harmless constituents by locating a plurality of mutually spaced wells into a groundwater region. A treating flow of hydrogen

peroxide solution is provided into the groundwater from one or more wells. The treating flow typically contains reaction surface enhancing reagents, which provide increased surfaces at which the reaction between the hydrogen peroxide and the hydrocarbon contaminants may occur. Further, a catalytic agent is also preferably incorporated into the treating solution or as a pre-injection into the groundwater region to promote the desired reaction between the hydrogen peroxide and hydrocarbons.

[0006] Recently, there has also been increasing interest in bioremediation technology. However, its use in treating groundwater has been relatively ineffective due to the complexity of the procedures and equipment required, including expensive and complex reactors. Moreover, current bioremediation techniques can cause adverse geochemical reactions and can introduce new toxic compounds into the groundwater. Additionally, current bioremediation systems, still require the use of non-organic catalysts or additives to cause the process to be completed in a reasonable period of time. These catalysts or additives raise other contaminant issues with respect to the groundwater.

[0007] It is known that naturally growing bacteria in the groundwater can break down groundwater contaminants. However, these bacteria are not always present in large enough quantities to be effective and can also be absent altogether. Moreover, these bacteria feed off oxygen and the lack of oxygen is the single biggest limiting factor

[illegible]

Summary Of the Invention

[0008] It is therefore an object of the present invention to provide a bioremediation method and system for groundwater treatment that is more effective than prior bioremediation systems.

[0009] It is another object of the present invention to provide a bioremediation method and system for groundwater treatment that is less expensive than prior bioremediation systems.

[0010] It is still another object of the present invention to provide a bioremediation method and system for groundwater treatment that treats contamination naturally and effectively.

[0011] It is still another object of the present invention to provide a bioremediation system that is

relatively easy and inexpensive to install and operate.

[0012] It is a related object of the present invention to provide a bioremediation system that can be installed with minimal site disturbance.

[0013] In accordance with the above and other objects of the present invention a bioremediation method and system is provided. The method includes providing a plurality of injection points extending from above ground to a subterranean body of groundwater. A source of substantially pure oxygen is provided. A supply of microbials is also provided. The oxygen and an amount of microbials are each delivered to the plurality of injection points and into the subterranean body of groundwater until the level of contaminants in the groundwater is reduced or eliminated.

[0014] The system includes a plurality of injection points extending below ground such that they intersect a body of groundwater. The system includes a supply of concentrated oxygen and a supply of microbials. The oxygen and microbials are each delivered to the plurality of injection points and into the groundwater.

[0015] The above objects and other objects, features and advantages of the present invention will be apparent from the following detailed description of best made for carrying out the invention to be taken in connection with the accompanying drawings and appended claims.

Brief Description of the Drawings

[0016] Figure 1 is a schematic illustration of an enhanced dissolved oxygen groundwater bioremediation system in accordance with a preferred embodiment of the present invention;

[0017] Figure 2 is a schematic illustration of the breakdown of contaminants in accordance with a preferred embodiment of the present invention; and

[0018] Figure 3 is an illustration of a flow meter of the system of Figure 1 in accordance with a preferred embodiment of the present invention.

Detailed Description of the Preferred Embodiment

[0019] Referring now to Figure 1 which illustrates a bioremediation system 10 in accordance with the present invention. The preferred bioremediation system 10 is preferably used to clean up biodegradable petroleum constituents that are present in contaminated groundwater. However, it should be understood, that the system 10 can be used to clean up other contaminants or constituents in groundwater and that the system may be used for a variety of other purposes.

[0020] The preferred bioremediation system 10 preferably includes a source of oxygen 12, such as a liquid oxygen tank. However, the oxygen can be provided in a variety of other forms. While the source of oxygen is preferably pure, it can also be of sufficient purity to accomplish the objectives of the present invention. For example, a source of

oxygen that has over 50% oxygen may also be sufficient. The source of oxygen 12 is preferably in communication with a control panel 14 to regulate the flow of oxygen from the oxygen source 12. The oxygen that flows to the control panel 14 is then conveyed to a plurality of injection sites 16 in a subterranean body of groundwater, generally indicated by reference number 18. The plurality of injection sites 16 are also in communication with a supply of microbials 20. The location of the injection sites 16 can be determined in a variety of ways, as discussed below.

[0021] The source of oxygen 12 is preferably coupled to the control panel 14 by a pressure hose 22 in order to convey the oxygen thereto. The pressure hose 22 has a first end 24 that is connected to the source of oxygen 12 and a second end 26 that is connected to the control panel 14. The source of oxygen 12 has a shut off valve 28 associated therewith which is located between the source of oxygen 12 and the first end 24 of the pressure hose 22. The shut off valve 28 allows the flow of oxygen from the source of oxygen 12 to the pressure hose 22 to be manually closed as desired. It should be understood that the valve 28 can also be electronically controlled. The second end 26 is preferably connected to a pressure regulator 30 which allows the pressure of oxygen exiting the source of oxygen 12 to be controlled. In the preferred embodiment, the pressure regulator 30 is set such that the pressure of oxygen exiting the oxygen source 12 is set for example, at 100 psi. It

should be understood that the pressure regulator 30 can be adjusted to regulate the flow of oxygen to a variety of different pressures.

[0022] The oxygen that exits the pressure regulator 30 enters a first conduit 32, which conveys the pressure regulated oxygen to an oxygen header pipe 34. The oxygen header pipe 34 has a plurality of flow meters 36 connected thereto and in fluid communication therewith. The pressure regulator 30, the first conduit 32, the oxygen header pipe 34, and the plurality of flow meters 36 are all preferably disposed within the control panel 14 and the control panel 14 is preferably mounted to a fence, wall or other structure 38. However, more or less items may be included in the control panel 14. The flow meters 36 regulate the flow of oxygen from the header pipe 34 to a respective outlet tube 40. The outlet tube 40 is also in communication with a source of microbials 42 through a microbial outlet tube 44. The microbials 42 exit the source 42 and pass through the microbial outlet tube 44 and enter the outlet tubes 40. Preferably, the microbials 42 are injected initially prior to injection of the oxygen. The amount of microbials is preferably determined based on the size of the contaminated area. Thereafter, the microbials will reproduce to ensure that an appropriate amount of food for the oxygen is present in the groundwater.

[0023] The outlet tube 40 is in communication with an injection tube 46 that terminates at a respective one of the plurality of injection sites

or points 16. Accordingly, the number of flow meters 36 that are utilized in a particular system will depend upon the number of injection sites that are determined to be necessary to clean up the groundwater at a given location. The conduits, pipes, tubes, and injection points are preferably constructed of PVC piping. The outlet tube 40 is preferably 1/4 inch tubing and the injection tubes 46 are preferably 1/2 inch tubing. The size and material of the pipes and tubes can obviously vary.

[0024] Referring now to Figure 2, which illustrates the desired chemical reaction induced by the preferred bioremediation system 10. As shown, a contaminant is present in the groundwater 18, as generally indicated by reference number 48. Oxygen molecules, as generally indicated by reference number 50, are fed to a microbial, which is generally indicated by reference number 52. The microbial 52 feeds off the oxygen molecules 50 and breaks down the contaminants 48 into a combination of water, as generally indicated by reference number 54, and carbon dioxide, as generally indicated by reference number 58. It will be understood that the contaminants are typically a COC chain, but could be a variety of other contaminants that require removal.

[0025] The system 10 is preferably installed at a site that was formerly a service station and has been determined to have groundwater that is contaminated with petroleum, whether through accidental or intentional spillage. As is known,

the groundwater can be tested through the use of a monitoring well to determine whether or not the groundwater has been contaminated. In accordance with the present invention, one way for determining the existence of contaminants is the absence or depletion of oxygen which indicates that naturally existing bacteria are feeding on the oxygen in an effort to breakdown the contaminants. It can be assumed that a body of groundwater has unacceptable levels of contamination when the percentage of oxygen in and around the groundwater is in the order of 0%-1%.

[0026] Once it has been determined that the groundwater is contaminated, in accordance with the present invention, the location of the injection points can be determined. The location of the injection points can be determined in a variety of different methods. Preferably, however, the injection points are located in a grid that takes into account the direction and flow rate of groundwater flow. By taking into account the groundwater flow, injection sites will be positioned to prevent contaminants from spreading. Typical grid determination is based on site specifics, but generally, a grid is based on two months of groundwater flow (e.g. if the groundwater flows 120 feet per year, the grid would be a 20 foot grid).

[0027] A plurality of monitoring wells 66 are preferably utilized to determine the extent and location of any contaminants so that the system usage can be maximized. Obviously, any number of

wells can be created. The injection sites 16 are preferably located in a grid pattern as shown (i.e. columns and rows), and then the injection tubes 46, which are connected to the source of liquid oxygen 12 and the control panel 14 and also the source of microbials 42 are installed to inject the pure oxygen into the groundwater at the injection sites 16.

[0028] Once the system is installed, the oxygen vapor will be regulated and metered to be delivered into the groundwater at a predetermined rate. The rate is preferably adjusted over time. The dissolved oxygen in the groundwater and the amount of oxygen in the soil gas are monitored to assure a sufficient flow of oxygen to the injection sites 16. Similarly, the oxygen is monitored to determine if too much oxygen is being added in order to prevent undue waste. Obviously, the rate and pressure of the oxygen vapor can be varied as needed. The effect of the system on the contaminants can be monitored periodically through the monitoring wells. Further, if the source of oxygen 12 becomes depleted, it can be easily replaced without disrupting the clean up process. Additionally, if the source of microbials 12 becomes depleted, it can also be easily replaced without disrupting the remediation process.

[0029] The preferred system is relatively inexpensive to install as it costs significantly less than prior systems. Moreover, the system operates twenty-four hours a day and requires no

electricity or maintenance to operate. Further, as there are no moving parts, there is nothing to lube, oil or grease. The system is also less susceptible to break down.

[0030] It has been determined that pure oxygen works to clean up contaminants in a body of groundwater more efficiently than ambient air and more efficiently and at less cost than various oxygen releasing compounds. By increasing the amount of dissolved oxygen, it has been found that the bacterial population increases by over a magnitude of a thousand. However, if the bacterial population is too small or nonexistent, it needs to be enhanced for the pure oxygen to work effectively. The issue thus becomes how to deliver the pure oxygen and the microbials into the ground and into communication with the groundwater. In accordance with the present invention, the preferred way is through the delivery system described above. Moreover, other delivery systems for conveying the oxygen and microbials to the injection sites may also be utilized.

Sub. A1 → **[0031]** However, in the preferred embodiment, a plurality of injection tubes 46 are utilized to convey the pure oxygen from the source 12 and microbials from the source 42 to the injection sites 16. While the source of oxygen 12 is preferably initially in liquid form, the pressure in the source 12 causes the liquid to turn to vapor. It is the pure oxygen vapor that is captured and then delivered through the delivery system and reacts

with the microbials. The injection points 16 and the injection tubes 46 can be installed by any of a variety of methods, including typical hollow stem auger with sand backfill. This is primarily for sites interbedded with clays and sites. Alternatively, the injection tubes 38 may be installed by known GeoProbe® (GeoProbe is a registered trademark of KEJR Engineering, Inc. of Kansas) installation techniques.

[0032] Preferably, the injection tubes 46 are installed by airjet injection. Airjet injection is a novel installation technique that is part of the present invention. In accordance with the present invention, airjet injection utilizes a compressor that is connected to an injection tube 46 via a hose. The air flow and pressure from the compressor act as a cutting tool and the injection tube 46 can be "injected" or inserted into the ground with minimal site description and minimal time and capital expense. It has been determined that up to eighty (80) or more injection points can be installed in a single day. This is significantly higher than the number of points that could be installed under prior installation methods.

[0033] As shown in more detail in Figure 3, each flow meter 36 is preferably connected to the oxygen header pipe 34 by a compression fitting 60 that allows oxygen at the regulated pressure to be delivered thereto. Each flow meter 36 is preferably mounted to a mounting board 62 or other structure in the control panel 14 and includes a pressure

indicator 64 that provides a visual indication of the pressure of fluid flowing therethrough. The outlet tubes 40 that are in communication with the outlet of the flow meters 36 preferably extend through a protective conduit 64 (Figure 1) which extends from the control panel 14 into the ground. The protective conduit 64 acts to shield and protect the outlet piping 40. The outlet piping 40 is preferably located at least one foot below the ground and runs generally parallel thereto. The injection tubes 46 are in communication with the outlet piping 40 and extend generally perpendicularly downward from the outlet piping 40. As shown, the outlet piping 40 intersects the groundwater 18 below the water table at designated injection sites 16 in order to deliver the pure oxygen and the microbials thereto.

[0034] While particular embodiments of the invention have been shown and described, numerous variations and alternate embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims.